

NEW MARKING AND MONITORING TECHNIQUES FOR FISH

8331900

SHORT DESCRIPTION:

Determine the biological and technical feasibility of using PIT-tag technology to passively obtain information on juvenile and adult salmonids, develop ancillary equipment to expand the PIT-tag system's capabilities to meet BPA and resource stakeholder information and research needs, and develop and evaluate enumeration technology.

SPONSOR/CONTRACTOR: NMFS

National Marine Fisheries Service

Earl F. Prentice, Fisheries Research Biologist

7305 East Beach Drive, Port Orchard, WA 98366

206/553-4219

Earl.Prentice@noaa.gov

SUB-CONTRACTORS:

University of Washington

GOALS

GENERAL:

Supports a healthy Columbia basin, Increases run sizes or populations, Adaptive management (research or M&E)

ANADROMOUS FISH:

Research, M&E

NPPC PROGRAM MEASURE:

3.2; 4.3C.1; 5.0F.9; 5.0F.14

RELATION TO MEASURE:

The Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program calls for assistance in collecting information to implement adaptive management practices including system monitoring and evaluation processes to aid in recovery of depleted salmonid populations (Measure 3.2). Specifically, the NPPC program recommends the following: Instructs fishery managers to develop needed technology for monitoring of wild and naturally spawning populations including development of Passive Integrated Transponder (PIT) tag detectors to monitor juvenile and adult populations and mobile counting weirs (Measure 4.3C.1). "On an expedited basis, fund the continued development of PIT tag technology..." (Measure 5.0F.9). Provide assistance to PSMFC in assessing merits of installing PIT tag detector facilities for adult fish at selected projects and

BIOLOGICAL OPINION ID:

NMFS Hydrosystem Operations Biological Opinion, Section VIII.A.

OTHER PLANNING DOCUMENTS:

National Marine Fisheries Service Snake River Salmon Recovery Plan (Sections 2.1.d; 2.3.b.4; 2.3c; 2.4.a; 2.6.c.2; and 2.9.d)

TARGET STOCK

Oncorhynchus spp.

LIFE STAGE

Juveniles and adults

MGMT CODE (see below)

W,(L)

BACKGROUND

Hydro project mitigated:

Columbia and Snake River Basin Projects

Project is an office site only

Habitat types:

Columbia and Snake River Basins

HISTORY:

BPA initiated a contract with NMFS in 1983 to determine the technical and biological feasibility of applying PIT-tag and associated technology to fishery problems in the Columbia River Basin (CRB) migration corridor. NMFS designed, evaluated, and implemented such a system using a 400-kHz frequency PIT tag. The PIT-tag system in conjunction with ancillary equipment

enables data to be passively collected on individual juvenile salmonids at selected locations within the CRB in near real time without handling fish.

The research and development effort of this project has and will continue to result in products that aid stakeholders in assessing the effectiveness of various actions taken to enhance the survival of juvenile and adult salmonids. Specifically, the research and development effort will provide 1) Alternative approaches that will enable fishery researchers and managers to address previously unanswered questions, and to provide accurate reliable data in near real time thus enabling effective decisions to be made regarding actions taken or to be taken; 2) Aid stakeholders in obtaining information required for the management of multiple species in a variety of habitats; 3) Products which can be used in genetic, physiology, behavior, and broodstock research efforts related to endangered species listed under ESA; 4) Products that can be used in obtaining survival and migration timing information on stocks of interest and provide accurate and timely data for evaluating water management strategies and fish passage/collection facilities; and 5) Aid all stakeholders by providing data needed for the management and restoration of salmonid and other fish stocks.

To achieve the above goals, the research and development effort is directed at 1) Refining and evaluating the mechanical operation of 2- and 3-way PIT-tag separation systems used to direct fish to predetermined locations; 2) Completion of the stand-alone multi-purpose computer program used in connection with fish diversion systems that direct fish to predetermined locations, control timed sub-samples, and collect PIT-tag data; 3) Development and evaluation of pass-by (horizontal and vertical) PIT-tag interrogation systems e.g., flat-plate PIT-tag interrogation system; and 4) Determining the performance of prototype 134.2-kHz PIT-tag interrogation systems that could replace the current 400-kHz PIT-tag interrogation system in the CRB.

BIOLOGICAL RESULTS ACHIEVED:

The biological studies associated with the PIT-tag project have been conducted in the laboratory, in the field under controlled conditions, and in the field under natural conditions. In the laboratory we have been able to determine 1) A suitable anatomical area for PIT-tag placement within salmonids that is acceptable from a biological and human standpoint; 2) The minimum size juvenile salmonid that could be effectively tagged with the PIT tag; 3) Host tissue response to the tag; 4) The effect of the tag on growth and survival for various age groups of fish; 5) Tag wound healing rate and disease occurrence from tagging; 6) Tag effect on swimming performance of parr, transitional, and smolted salmon; 7) Effect of electromagnetic fields produced by the PIT-tag interrogation system on the biology of salmon and a surrogate fish, Medaka; 8) Predator avoidance of tagged fish; and 9) PIT-tag retention in various sizes and species of salmonids in relation to traditional tags and marks.

In the field under controlled conditions we have determined: 1) Reaction of predators to PIT-tagged and traditionally marked and tagged fish in both clear and turbid water; 2) The growth, survival, and tag retention of several species of salmonids held for extended periods in both fresh water and sea water; and 3) The behavior of PIT-tagged juvenile salmonids to various geometry and colors of PIT-tag interrogation passageways.

In the field under natural conditions we have determined: 1) Return rate, tag retention, size at return, and timing of PIT-tagged coho salmon released to the wild; 2) Overwinter survival (recapture rate) of coho salmon released to the wild in relation to coded wire tagged and other traditionally tagged and marked fish; 3) The reaction of naturally migrating coho salmon to electromagnetic field produced by an underwater PIT-tag interrogation system ; and 4) The behavior of fish ascending fish ladders using video equipment.

Activities that support the CRB PIT-tag system and consequently indirectly enhance the salmon recovery effort includes the following ancillary systems development: 1) PIT-tag injectors both hand-held and semi-automatic; 2) A computer based PIT-tag data entry station; 3) Rectangular slide-gate fish diversion system; 4) 2- and 3- way fish diversion systems; 5) The first computer program for recording PIT-tagged fish passing through interrogation units at dams; 6) The first rectangular, round, and flat-plate PIT-tag interrogation systems for juvenile salmonids; 7) The first adult salmon PIT-tag interrogation units; 8) The first underwater towed PIT-tag interrogation system; 9) The first CRB PIT-tag data base; 10) The first computer controlled juvenile fish diversion system; and 11) First multi-tasking computer program for controlling fish separation, subsampling, and data collection.

PROJECT REPORTS AND PAPERS:

Brannas, E., H. Lundqvist, E. Prentice, M. Schmitz, K. Brannas, and B. Wiklund. 1994. Use of the passive integrated transponder (PIT) in a fish identification and monitoring system for fish behavior studies. *Trans. Am. Fish. Soc.* 123:395-401.

Flagg, T.A., and E. F. Prentice. 1988. The PIT tag system and its suitability in sockeye salmon. Sockeye culture workshop, Ketchikan, Alaska. Alaska Dept. of Fish and Game. p 8.

Maynard, D. J., D. A. Frost, F. W. Waknitz, and E. F. Prentice. 1996. The vulnerability of marked age-0 steelhead to a visual predator. *Trans. Am. Fish. Soc.* 125:330-333.

McCutcheon, C.S, E.F. Prentice, and D.L. Park. 1994. Passive monitoring of migrating adult steelhead with PIT tags. *N. American J. Fish. Manage.* 14:220-223.

Peterson, N. P., E. F. Prentice, and T. P. Quinn. 1994. Comparison of sequential coded wire and passive integrated transponder tags for assessing overwinter growth and survival of juvenile coho salmon. *N. Am. J. Fish. Manage.* 14:870-873.

Prentice, E. F. 1990. A new internal telemetry tag for fish and crustaceans. NOAA Technical Report NMFS 85. Proceedings Fifteenth U.S.-Japan Meetings on Aquaculture. Albert Sparks (editor). p 9.

Prentice, E. F., T. A. Flagg, and C. S. McCutcheon. 1987. A study to determine the biological feasibility of a new fish tagging system. Report to Bonneville Power Administration, Contract DE-179-83BP11982, 109 p. plus Appendixes. (Available from Northwest Fisheries Science Center, 2725 Montlake Blvd. E., Seattle, WA 98112-2097.)

Prentice, E. F., T. A. Flagg, and C. McCutcheon. 1990. Feasibility of using implantable passive integrated transponder (PIT) tags in salmonids. *Am. Fish. Soc. Symp.* 7:317-322.

Prentice, E. F., T. A. Flagg, C. McCutcheon and D. Brastow. 1990. PIT-tag monitoring systems for hydroelectric dams and fish hatcheries. *Am. Fish. Soc. Symp.* 7:323-334.

Prentice, E. F., T. A. Flagg, C. McCutcheon, D. Brastow and D. Cross. 1990. Equipment, methods, and an automated data-entry station for PIT tagging. *Am. Fish. Soc. Symp.* 7:323-334.

Prentice, E. F., D. Maynard, S.L. Downing, D. A. Frost, M. S. Kellett, D. A. Bruland, P. SparksMcConkey, F. W. Waknitz, R. N. Iwamoto, K. McIntyre, and N. Paasch. 1994. A study to determine the biological feasibility of a new fish tagging system, 1990-93. Report to Bonneville Power Administration, Contract DE-179-83BP11982.

Prentice, E. F. and D. L. Park. 1984. A study to determine the biological feasibility of a new fish tagging system. Report to Bonneville Power Administration, Contract DE-A179-83BP11982, 38 p. plus Appendix.

Prentice, E. F., D. L. Park, T. A. Flagg, and C. S. McCutcheon. 1986. A study to determine the biological feasibility of a new fish tagging system. Report to Bonneville Power Administration, Contract DE-179-83BP11982, 79 p. plus Appendixes.

Prentice, E. F., C. W. Sims, and D. L. Park. 1985. A study to determine the biological feasibility of a new fish tagging system. Report to Bonneville Power Administration, Contract DE- I 79-83BP 1 1982, 34 p. plus Appendixes.

ADAPTIVE MANAGEMENT IMPLICATIONS:

This work represents the continuation of several research projects that address the transition from a 400-kHz to a 134.2 kHz International Standards Organization (ISO) -based transponder/ transceiver system, the development and evaluation of associated technology that can be used to identify both smolts and adult salmon, and the development and evaluation of ancillary equipment for passive data collection and diversion of fish. The continued development of the PIT tag and ancillary equipment will further expand the systems capabilities to address issues expressed in both the Biological Opinion for operation of the Federal Columbia River Power System and the proposed Snake River Salmon Recovery Plan.

The research and development effort of this project has and will continue to result in products that aid stakeholders in assessing the effectiveness of various actions taken to enhance the survival of juvenile and adult salmonids. Specifically, the research and development effort will provide: 1) Alternative approaches that will enable fishery researchers and managers to address previously unanswered questions, and to provide accurate reliable data in near real time, enabling effective decisions to be made; 2) Aid stakeholders in obtaining information required for the management of multiple species in a variety of habitats; 3) Products which can be used in genetic, physiology, behavior, and broodstock research efforts related to endangered species listed under ESA; 4) Products that can be used in obtaining survival and migration timing information on stocks of interest and provide accurate and timely data for evaluating water management strategies and fish passage/collection facilities; and 5) Aid all stakeholders by providing data needed for the management and restoration of salmonid and other fish stocks.

To achieve the above goals, the research and development effort is presently directed at: 1) Refining and evaluating the mechanical operation of 2 and 3-way PIT-tag separation systems used to direct fish to predetermined locations; 2) Completion of the stand-alone multi-purpose computer program used in connection with fish diversion systems that direct fish to predetermined locations, control timed sub-samples, and collect PIT-tag data; 3) Development and evaluation of pass-by (horizontal and vertical) PIT-tag interrogation systems e.g., flat-plate PIT-tag interrogation system; and 4) Determining the performance of prototype 134.2-kHz PIT-tag interrogation systems that could replace the current 400-kHz PIT-tag interrogation system in the CRB.

The present project focuses on products that remotely and non-intrusively direct and collect information on juvenile PIT-tagged fish as they pass specific interrogation points. Future development efforts should focus on the interrogation of PIT-tagged adult fish and the passive collection of other types of information (i.e., length and physical condition) on PIT-tagged fish. In addition, products should be developed that non-intrusively collect information (i.e., numbers, size, physical condition, and species) on non-tagged fish. Such systems would reduce fish handling and stress, provide accurate reliable information in near real time, reduce overall cost of information gathering, and enable managers to better evaluate the effectiveness of stock restoration efforts.

PURPOSE AND METHODS

SPECIFIC MEASUREABLE OBJECTIVES:

- 1) Develop and evaluate a 2-way and 3-way side-to-side fish diversion system and improve the performance and reliability of the 3-way rotational PIT-tag fish diversion systems used to direct fish to predetermined locations.
- 2) Complete the stand-alone multi-purpose computer program used in connection with fish diversion systems that direct fish to predetermined locations, control timed sub-samples, and collect PIT-tag data.
- 3) Continue to develop and evaluate the 400-kHz flat-plate (pass-over) PIT-tag interrogation system used at Bonneville Dam.
- 4) Develop a 134.2-kHz flat-plate (pass-over) PIT-tag interrogation system for Bonneville Dam.
- 5) Develop horizontal and vertical 134.2-kHz pass-by PIT-tag interrogation system for a variety of applications .
- 6) Determine the performance of prototype 134.2- kHz PIT-tag transceiver systems at a dam that could replace the current 400-kHz PIT-tag system used in the CRB.

CRITICAL UNCERTAINTIES:

None

BIOLOGICAL NEED:

This work represents the continuation of several research and development tasks that address the resource stakeholders need for accurate reliable information that is assessable in near real time. Present work focuses on determining the technical feasibility of a 134.2- kHz International Standards Organization (ISO) tag/transceiver system and associated technology that can be used to identify both smolts and adult salmon, the development of ancillary equipment, and the resulting products' effect on fish. The continued development of the PIT tag and ancillary equipment will further expand the system's capabilities to address issues expressed in both the Biological Opinion for operation of the Federal Columbia River Power System and the proposed Snake River Recovery Plan.

HYPOTHESIS TO BE TESTED:

- 1) New and old versions of fish diversion systems used to direct fish to pre-determined locations are equal in performance and reliability.
- 2) New and old stand-alone multi-purpose computer program used in connection with fish diversion systems to direct fish to predetermined locations, control timed sub-samples, and collect data are equal in performance.
- 3) The 400-kHz flat-plate (pass-over) PIT-tag interrogation system developed for Bonneville Dam will operate and detect 400-kHz PIT-tagged juvenile salmonids at the same efficiency level as in 1996.
- 4) The prototype 134.2-kHz flat-plate (pass-over) PIT-tag interrogation system developed for Bonneville Dam will read 134.2-kHz PIT-tags.
- 5) The prototype 134.2-kHz vertical and horizontal pass-by PIT-tag interrogation systems will read 134.2-kHz PIT-tags.
- 6) The performance (tag reading ability and reliability) of the 134.2-kHz system at a dam is equivalent to that of the existing 400-kHz system.

METHODS:

The PIT-tag research and development effort is composed of both biological and mechanical work elements. Biological oriented studies use standard scientific protocol and fish husbandry techniques as needed. All studies are replicated and data subjected to appropriate statistical tests. When fish are required in studies, proper permits are obtained. Study results are reported at workshops, in BPA reports, and in the scientific literature.

Those projects which are non-biological in nature use the expertise of mechanical and electrical engineers, fabricators, machinists, and computer programmers. Design drawings are often prepared that are later altered as the prototype equipment is fabricated and evaluated. All systems are judged against a set of evaluation standards. The evaluation process takes place in both the laboratory (dry-testing) and field (wet-testing). Modifications are made as indicated through the testing program. Once alterations are made, the systems are re-evaluated. Resource stakeholders are solicited for their comment and are provided an opportunity to examine the systems at various steps during development.

PLANNED ACTIVITIES

SCHEDULE:

Planning Phase	Start 1997	End 2001	Subcontractor As required
-----------------------	-------------------	-----------------	----------------------------------

Task The primary research and development effort for 1997-98 will be focused on flat-plate (pass-over) PIT-tag interrogation technology for juvenile salmonids (the technology is also directly applicable to adult salmon interrogation), continuance of work directed at improving tag retention in sexually maturing salmonids, and completing reports associated with projects

completed during the 1996-97 period.

For the period of 1998-2001, the program will focus on 1) expanding the capabilities of the Passover/pass-by PIT-tag interrogation systems so it can be used in small streams and locations within the juvenile collection facilities prior to major dewatering; 2) assist BPA in evaluating and installing new 134.2-kHz PIT-tag interrogation systems within the CRB; 3) complete the evaluation of MULTIMON data collection and systems control computer program; and 4) integrate passive data collection (e.g., counting, fish condition, and length monitoring) systems into designated information gathering sites within the CRB.

Implementation Phase **Start** 1997

End ongoing

Subcontractor As required

Task Products resulting from this research and development effort will be implemented during or after the field evaluation phase of study.

PROJECT COMPLETION DATE:

2001

CONSTRAINTS OR FACTORS THAT MAY CAUSE SCHEDULE OR BUDGET CHANGES:

None

OUTCOMES, MONITORING AND EVALUATION

SUMMARY OF EXPECTED OUTCOMES

Expected performance of target population or quality change in land area affected:

- 1) Develop and improve performance and reliability of PIT-tag diversion systems used to direct fish to predetermined locations. The development work will result in a suite of fish diversion systems that will address a number of research and monitoring needs within the CRB in addition to reducing the need to handle and stress fish.
- 2) Completion of the stand-alone multi-purpose computer program used in connection with fish diversion systems and other tasks will result in a reduction in the number of computer programs and independent control systems; a centralized computer controlled systems that will provide overall better system and information reliability; and flexibility for future research and management needs.
- 3) Continue to develop and evaluate the 400-kHz flat-plate (pass-over) PIT-tag interrogation system used at Bonneville Dam. This system will provide near real-time data from PIT-tagged fish during the 1997 field season.
- 4) Develop a 134.2-kHz flat-plate (pass-over) PIT-tag interrogation system for Bonneville Dam. This system will enable PIT-tagged fish to be interrogated after the conversion to the 134-kHz system takes place in the CRB.
- 5) Develop horizontal and vertical 134.2-kHz pass-by PIT-tag interrogation system for a variety of applications. This effort could result in technology that will enable resource stakeholders to obtain near real-time, accurate PIT-tag information on fish in areas not currently possible (i.e., adult fish ladders, small streams, down stream migrant channels, etc.). In addition, these tools may enable fish to be interrogated with little or no dewatering.
- 6) Determine the performance of prototype 134.2-kHz PIT-tag transceiver systems at a dam. The new system could replace the current 400-kHz PIT-tag interrogation system used in the CRB. This effort could result in all current PIT-tag interrogation systems in the CRB being replaced with more reliable, accurate, and less costly PIT-tag systems.

Contribution toward long-term goal:

Reliable passive (non-intrusive) cost efficient monitoring and information gathering technology that will enable resource stakeholders to obtain accurate reliable information in near real-time. This technology is needed to evaluate the effectiveness of various stock recovery programs and needs.

Indirect biological or environmental changes:

If accurate, reliable non-invasive data collection systems can be developed, then the need for handling or channeling fish in addition to the need for complex fish collection systems may be reduced.

Coordination outcomes:

Milestones/dates to end of the project: 1) Continue to develop an interrogation system that separates fish by tag code, thus reducing fish handling and enabling tagged fish to be directed as desired by investigators; 2) Evaluate the feasibility of a pass-by (horizontal and vertical flat-plate) volitional tag interrogation system for small streams, fish collection channels, wet-separators, over fall wiers, and vertical slots in adult fish ladders; 3) Evaluate the feasibility of converting the present PIT-tag system used in the CRB to a system that is compatible with other manufacturers' PIT tags and interrogation equipment (ISO-based system); 4) Interface with stakeholders to ensure the effective transfer of developmental prototype products to operational products; and 5) Develop with BPA both project management and program management plans that allow for effective decision making, effective definition of long term objectives and performance standards.

MONITORING APPROACH

Those projects that are non-biological in nature, use the expertise of mechanical and electrical engineers, fabricators, machinists, and computer programmers. Design drawings are often prepared that are later altered as the prototype equipment is fabricated and evaluated. All systems are judged against a set of evaluation standards. The evaluation process takes place in both the laboratory (dry-testing) and field (wet-testing). Modifications are made as indicated through the testing program. Once alterations are made the systems are re-evaluated.

Those tasks that have biological components use standard scientific protocol and fish husbandry techniques as needed. All studies are replicated and data subjected to appropriate statistical tests. When fish are required in studies, proper permits are obtained. Study results are reported at workshops, in BPA reports, and in the scientific literature.

Data analysis and evaluation:

Tools and systems resulting from these research and development effort will be evaluated using performance criteria established by NMFS and the fisheries community. Data will be subjected to statistical tests and incorporated into test results.

Information feed back to management decisions:

Information will be transferred to management and regional resource stakeholders via reports, publications, workshops, and direct contact.

Critical uncertainties affecting project's outcomes:

Each task within the project uses development milestones and performance criteria to gauge progress. If problems prevent a milestone from being accomplished in a timely and efficient manner, that task is re-evaluated. If upon re-evaluation no solution can be found to the problems preventing the accomplishment of a milestone, the task is terminated.

EVALUATION

- 1) Review progress reports and publications submitted to BPA.
- 2) Specific Element: See publication and report list.
- 3) Attend workshops where task progress is discussed.
- 4) Specific Examples: Several CRB PIT-tag workshops, program reviews have been conducted to inform resource stakeholders of the progress of research and development tasks.
- 5) Attend demonstrations of prototype tools.
- 6) Specific example: In 1996 a demonstration of the first pass-by PIT-tag interrogation system was given at Bonneville Dam.

Incorporating new information regarding uncertainties:

If new information becomes available about uncertainties affecting the project, the information is incorporated into the task progress review process.

Increasing public awareness of F&W activities:

The technology developed from this research and development effort are being adopted by resource stakeholders on a national and international basis. The public at large is thus becoming aware of the region's efforts to protect, mitigate, and enhance fish and wildlife through the use of these tools.

RELATIONSHIPS

RELATED BPA PROJECT

8910700 Epidemiological Survival Method

9102800 Monitoring Smolt Migration of Wild Snake River
Sp/Sum Chinook

9302900 Survival Estimation for Dam/Reservoir Passage

9008000 Columbia Basin Pit-tag Information System

RELATIONSHIPProvided statistical methodology which permitted survival
estimation in concert with PIT-tag technology in the CRBSurvival, travel time, distribution, and downstream migration of
PIT-tagged wild Snake River spring chinook tagged as parrDevelopment of PIT-tag technology and detector systems in the
CRB made possible the precise reservoir and dam survival and
travel time estimates for juvenile salmonids

CRB PIT-Tag Information System

OPPORTUNITIES FOR COOPERATION:

For the goals of this project to be obtained in a timely and cost efficient manner, the cooperation of all stakeholders is required. This cooperation is obtained through open lines of communication and a common desire to restore the resource. The success of the program to date reflects this spirit of cooperation.

COSTS AND FTE**1997 Planned:** \$800,000**FUTURE FUNDING NEEDS:**

<u>FY</u>	<u>\$ NEED</u>	<u>% PLAN</u>	<u>% IMPLEMENT</u>	<u>% O AND M</u>
1998	\$850,000	2%	98%	
1999	\$875,000	2%	98%	
2000	\$900,000	2%	98%	
2001	\$900,000	2%	98%	

PAST OBLIGATIONS (incl. 1997 if done):

<u>FY</u>	<u>OBLIGATED</u>
1983	\$81,220
1984	\$353,866
1985	\$746,800
1986	\$400,900
1987	\$429,800
1988	\$1,001,400
1989	\$1,847,700
1990	\$1,063,700
1991	\$1,206,200
1992	\$1,200,000
1994	\$1,406,400
1995	\$460,000
1996	\$681,800

TOTAL: \$10,879,786

Note: Data are past obligations, or amounts
committed by year, not amounts billed. Does not
include data for related projects.

<u>FY</u>	<u>OTHER FUNDING SOURCE</u>
1998	NMFS
1999	NMFS
2000	NMFS
2001	NMFS

<u>AMOUNT</u>	<u>IN-KIND VALUE</u>
	\$50k
	\$60
	\$70
	\$70

OTHER NON-FINANCIAL SUPPORTERS:

U.S. Army Corps of Engineers and Pacific States Marine Fisheries Commission.

1997 OVERHEAD PERCENT: 45.6% of total direct labor costs**HOW DOES PERCENTAGE APPLY TO DIRECT COSTS:**

Applies to total direct labor costs only.

CONTRACTOR FTE: 10FTE

SUBCONTRACTOR FTE: 1
